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PAPER NUMBER

FUTURE BALLISTIC MISSILE REQUIREMENTS: A FIRST LOOK

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Abstract. The Minuteman III, the mainstay of the United States' intercontinental ballistic missile (ICBM) force, was built with 1960s technology. Programs now underway should extend the system's life past 2020. What happens after that? The Defense Planning Guidance directs the Air Force to pursue Minuteman III replacement concepts, and recent studies agree a land-based nuclear deterrent will be needed indefinitely. The future system [now known as Minuteman IV (MM IV)] could use a mix of existing and new hardware, and/or some combination of military and commercial components. The front end may resemble today's reentry system or it could carry a maneuvering reentry vehicle. Alternatively, the force structure of the future may employ a mix of ballistic and maneuvering front ends. Which options are pursued depends on factors including the threat, arms control agreements, and the ultimate service life of Minuteman III. Air Force Space Command's Directorate of Requirements initiated the Ballistic Missile Requirements (BMR) study in 1998 to document requirements for the 2020 - 2040 time frame and provide options. The definition of requirements and options is key to focusing our research efforts and our dollars to field the most cost-effective deterrent ICBM force for the future.

Introduction

The Minuteman III (MM III) ICBM system has served the U.S. for almost 30 years as the nation's primary land-based strategic nuclear deterrent. Current efforts underway will extend Minuteman's life span to the 2020 time frame. The development and acquisition lead times for a major weapons system are so long that planning and technology development must begin now for Minuteman's replacement.

The Ballistic Missile Requirements (BMR) study documents the potential requirements and the options to meet those requirements for the 2020 to 2040 time frame. The study was conducted from 1998 to 2000 by Headquarters Air Force Space Command's Directorate of Requirements Force Applications Division (AFSPC/DRM) and its contractors.[1] This paper briefly summarizes the study effort for what HQ AFSPC now refers to as MM IV.

Before the Department of Defense (DoD) recommends the development and purchase of any new military capability, the requirement for this capability must be established. Moreover, it must be shown that this requirement is important enough to be funded over competing demands. Finally, DoD must demonstrate the recommended solution is capable, feasible, and affordable.

Background

The U.S. has maintained a Triad of strategic forces, including land-based ICBMs, for almost 40 years. The other two "legs" of the Triad are manned bombers and submarine-launched ballistic missiles (SLBMs). This last role is currently filled by Trident submarines, which will eventually be fitted entirely with the Trident II or D5 missile.

The Minuteman System

The current mainstay of the land-based ICBM force, the MM III, was first deployed in 1970. The last missiles were built in 1978, although two of the three stages have been refurbished once since then. Five hundred Minutemen are now on continuous alert, along with 50 larger Peacekeeper (or MX) missiles.

The MM III is composed of three solid-fuel stages, a missile guidance set, a Propulsion System Rocket Engine (PSRE), and a reentry system (RS). The PSRE is a small liquid-fueled stage that provides power for the final velocity and direction adjustments before the reentry vehicles (RVs) are sent into their ballistic arcs. The system can dispense up to three RVs. Current RVs have no terminal guidance system: once released from the missile, they follow ballistic arcs in much the same manner as artillery shells.

Policy and Requirements

The continuation of the Triad is still a cornerstone of U.S. defense policy. The latest *National Security Strategy*, issued in 1999, states, "...the U.S. will continue to maintain a robust triad of strategic forces sufficient to deter any potential adversaries who have or seek access to nuclear forces ..."[2] Specifically, the most recent edition of the top-level *Defense Planning Guidance*[3] directs the Air Force to examine concepts to begin replacing MM III by 2020.

The current Administration has supported this policy to the point of adding funds to maintain on alert the Peacekeeper ICBM, which had been slated for deactivation. (The Peacekeeper will still be retired if the START II arms control treaty enters into force, which is dependent upon the actions of the U.S. Senate.)[4] The Minuteman force will remain on alert under START II, although all Minuteman missiles will be switched to a single reentry vehicle (SRV) configuration due to START II's ban on multiple warheads.

Recent Studies

In July 1998, the Defense Science Board (DSB) reported on the need for a future deterrent system. The DSB's Task Force on Nuclear Deterrence stated that, even with the lowest plausible level of nuclear forces under a still-hypothetical START III agreement, the Triad remained essential to a stabilizing deterrent force. Moreover, the value of the ICBM leg "...increases the most with declining forces. As the total numbers on both sides moves the situation from warhead-rich to target-rich, the single-warhead silo-based ICBM becomes highly stabilizing."[5]

The DSB added, "Without the ICBMs, surprise attacks against a handful of bomber bases and SSBN (submarine) facilities, with plausible deniability, could drastically alter the correlation of forces." "Planning for a new ICBM would need to begin around 2000 for production to begin around 2017."[6]

Also in July 1998, the National Defense University and Lawrence Livermore National Laboratory delivered the second major nuclear weapons study, "US Nuclear Policy in the 21st Century." This study concluded:

- "The United States will need a nuclear deterrent well into the 21st century."
- "The United States should retain the three legs of the Triad."
- "As Russian nuclear forces are reduced, the US single-warhead, silo-based ICBMs are of increasing value in deterring large-scale attack."[7]

The most recent AFSPC Strategic Master Plan states:

> "For nearly 50 years, the USAF ICBM force has maintained a safe and secure prompt, global, nuclear strike capability that has maintained strategic deterrence, a capability that cannot be compromised. Our nuclear force will be upgraded and/or replaced as required to maintain our strategic nuclear posture throughout the three time periods in accordance with NCA direction.
>
> Finally, we will invest in the Ballistic Missile Requirements (BMR) program to maintain our strategic deterrent forces through the far-term. Minuteman III ICBMs will begin to age out around 2020. The BMR study, initiated under the ICBM Long-range Requirements Planning program, is examining options that include another Minuteman life extension program, a new missile system and a variety of other concepts which may meet future Force Applications requirements... The BMR initiative is critical to maintaining strategic deterrence past 2020.[8]

Missions

The primary responsibility of the MM IV, as with today's ICBMs, will continue to be strategic nuclear deterrence. Ancillary missions are certainly possible. The study examined ways a future ballistic missile could meet additional validated Triad requirements. These are

documented in finalized or draft requirements documents for capabilities including counters to Strategic Relocateable Targets (such as mobile missile launchers) and Hard and Deeply Buried Targets. There is also an established need for Agent Defeat Weapons (ADW) - that is, weapons designed to destroy chemical or biological agents. The study also examined meeting requirements for non-nuclear delivery systems for Prompt Global Strike. The main focus, however, was on the strategic needs, which are documented in a draft Mission Need Statement (MNS) for a future Land-Based Strategic Nuclear Deterrent, now in coordination.

MM IV Options

There are two basic alternatives for the MM IV:

- A remanufactured Minuteman III force, with its life extended yet again.
- A new missile, which could be entirely new or a hybrid of existing and new components.

Within these two options, the possibilities can be subdivided by booster size. The booster for the MM IV could be:

- Minuteman class (the MM III or a similar-size stack, with a gross liftoff weight (GLOW) of 32,000 - 41,000 kg.)
- Minuteman-Plus class (a broad range intermediate between the current MM III and Peacekeeper missiles, with a GLOW of 41,000 - 82,000 kg.)
- Peacekeeper class (based on or comparable to Peacekeeper, with a GLOW of 82,000-91,000 kg.). Note this weight is under the first START agreement "heavy ICBM limit of 106,000kg.

Any of these classes could have two or three stages, depending on the design and the motors used. Two-stage boosters, if available technology will allow them to fulfill the mission, are very attractive for reasons of cost and simplicity.

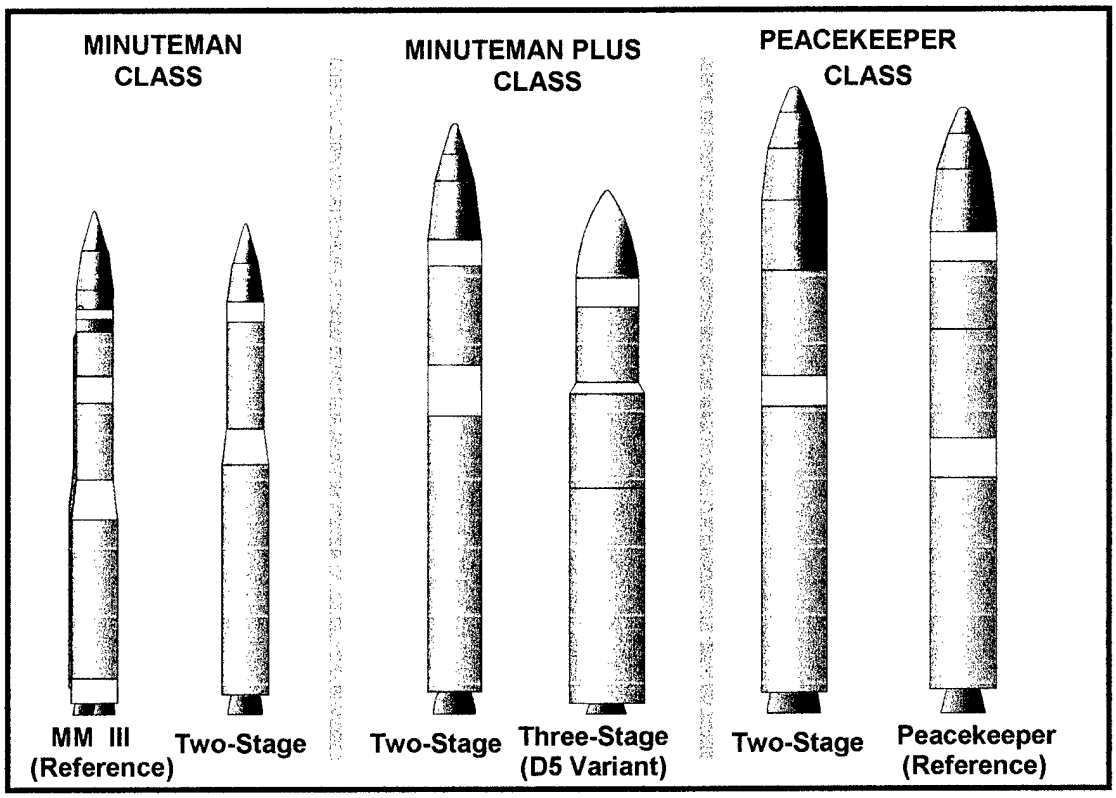

Figure 1. MM IV Booster Options.

The Drivers: Range and Payload

The necessary booster size will be determined by the range and payload requirements. Range requirements from 8,300 kilometers (km) and 29,600 km are being considered, along with possible front end weights anywhere between 500 and 3,600 kg. The larger front end sizes and longest ranges are applicable to trajectory-shaping vehicles (TSVs). TSVs are gliding front ends which would be heavier but reach farther than purely ballistic RVs used on MM III and Peacekeeper today.

The payload options were divided for the study into two classes: ballistic reentry systems (RSs) and TSVs.

The ballistic reentry options included:

- The system used now on MM III, in which is ballistic RV is separated from the other RS components.

- An integrated front end (IFE). The IFE would be a consolidated redesign of the post-boost system, combining the current functions of the PSRE, the missile guidance system (MGS) and the RS itself.

The possible variants of the TSV concept can be grouped into three options:

- The Mk 11 Aeroshell (TSV Type I). The Mk 11 Aeroshell was previously studied under the High Speed Precision Penetrator (HSPP) project, examined by AFSPC in 1998-99. This system is based on the aeroshell from the Mk 11 RV, which was carried by the now-retired Minuteman II ICBM. This aeroshell would be modified with flaps and/or an internal moving mass to provide some cross-range steering capability. The Mk 11 system would be optimized for the deep penetration mission against hard and deeply buried targets.

- The Strategic Advanced Front End (SAFE). The SAFE concept, also known as TSV Type II, would use an aerodynamic reentry body with a lift-over-drag (L/D) ratio of approximately 2. Designed to fit under a MM III payload shroud and equipped with steering flaps, the SAFE would provide a larger footprint than the Mk 11 (that is, it could cover a larger potential target area when lofted on a given trajectory) and could carry a variety of payloads.

- The TSV Type III. The TSY Type III would be a larger, more advanced front end, with a higher L/D ratio than the Type II. It would resemble a lifting body more than a traditional RV shape. It would offer the greatest degree of steerability and flexibility. The Type III could be lofted by a MM III-class booster, but would not fit under a MM III payload shroud.

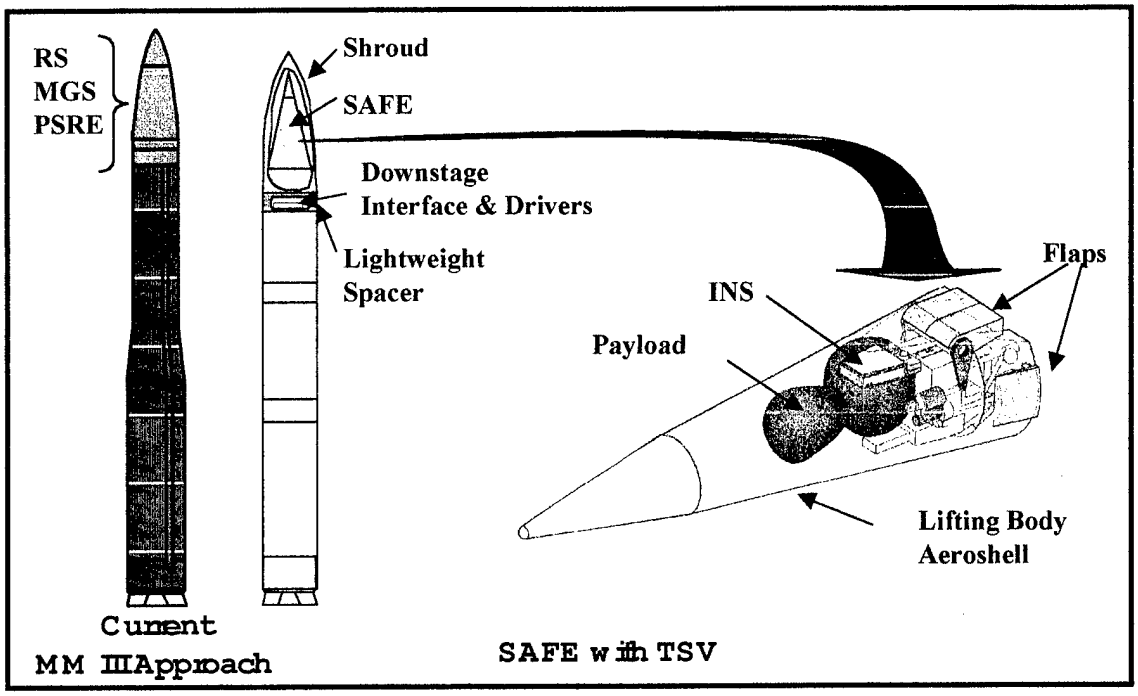

Figure 2. Two Possible MM IV Front End Concepts. (NOTE: The TSV Type II shown represents only one of many conceivable design concepts.)

Minuteman Life Extension

The life of the MM III has been extended by refurbishing the upper stages and making numerous improvements to the launch facilities and other support systems. Now in progress are the Propulsion Replacement Program, which will repour the first two solid-fuel stages and replace the third stage, the Guidance Replacement Program, which will replace the guidance computer and electronics, and a PSRE life extension program. These efforts, if funded to completion, will extend the life of the system to the 2020 time frame.

In the BMR study, the ICBM System Program Office (SPO) and contractor TRW examined the possibility of another round of life extension programs. While it is difficult to foresee all possible problems with the system, this review concluded that another life extension appears feasible.[9]

Feasibility alone will not determine whether this course is followed. Many other factors could come into play. One example is sustainability. Even if the life span of Minuteman can be extended, it is a decades-old system relying on parts and subsystems from manufacturers which, in many cases, no longer exist. Finally, critical structural flaws or aging-induced deficiencies which are not detectable today could appear before the next life extension cycle.

New Missile

It is conceivable that, even if all components of the Minuteman could be affordably extended and supported, this may not be the best direction to take. Keeping some or no Minuteman components and replacing others with new technology offers several advantages.

The Minuteman is designed to place RVs into a precise ballistic trajectory. This method of delivery, sometimes referred to as "throwing rocks," may not provide the flexibility needed for future missions. If the MM III booster stack proves capable and long-lived enough, an IFE or SAFE, with up to date guidance and control technology, could be designed and placed atop the existing stages.

A new missile might also involve mixing Air Force ICBM components, like upper stages, with those derived from the Navy's D5 or its successor. Another option would involve a mixture of existing ICBM or SLBM components with some commercial off the shelf (COTS) items. The possibilities here encompass a wide range of options, making it all the more critical to continue expeditiously the work of narrowing them down.

The final variant of this option is to build an entirely new missile. The principal advantage of a new missile is that all systems would be just that – new. A new system could incorporate the most current technology and could be designed for affordable maintenance and a long service life. Finally, a new missile could be designed to precisely match the projected mission requirements with capability.

The Commonality Question

It has been proposed many times that the two strategic missile forces, Air Force and Navy, use the same missile. While this has obvious appeal, it does present some technical challenges which must be overcome.

The Navy's Trident submarines impose an absolute design constraint on their missiles, which must fit in a certain space. The D5 missile used in the Trident II system is 13.4 m long and 2.1 m in diameter. It weighs 58,500 kg. The MM III, by comparison, is 18 m long and has a maximum diameter of 1.67 m. Any future submarine is unlikely to have larger missile accommodations than the Trident, the largest U.S. submarine ever built.

The D5's range is officially given as over 7400 km, compared to the MM III's 9700 km.[10] Based on these figures, an existing D5 missile placed in a Minuteman silo (which is physically possible, although complex, given the D5's need for a cold-gas ejection launch system) would not provide the full range of targeting options offered by the current Minuteman. (Any consideration of a land-based D5 variant assumes a D5 could be converted to a single-RV design. The D5 is designed as a multiple-warhead missile, which is permissible under START II for SLBMs but not for ICBMs.)

Instead of a true common missile, it may be that the next-generation Air Force and Navy missiles would share technology in as many areas as possible. Likely examples are guidance systems and solid propellant.

Infrastructure

There is a great deal more involved with a missile system than just the missile. If Minuteman were to be replaced with a new system, especially one having different dimensions, new support requirements would include:

- Technical data
- Transportation and Handling Equipment
- Test equipment
- Training equipment (simulators, etc.)
- New or modified storage facilities
- Test launch facilities

These concerns do not rule out replacing Minuteman. They are factors which must be included in any calculations of the costs and benefits of each possible option. The Minuteman class booster option was sized to minimize these types of impacts to infrastructure.

Facing the Cost

Whatever MM IV option is chosen, DoD must make the case to Congress and the President that the expense is warranted.

Strategic force spending has declined from $22.4B in FY90 to $7.6B in FY98, and is projected to remain flat at approximately $8.1B per year.[11] (***NOTE:*** *All cost figures in this paper unless otherwise identified are in Fiscal Year 1999 (FY99) dollars.*) The services are struggling to fit missile life extension programs under these ceilings.

The most recent example we have for a strategic missile development program is the Small ICBM (SICBM), a.k.a. Midgetman. This single-warhead missile entered development in 1984 and was canceled in 1991, after two flight tests.

Cost estimates for development, production, and deployment of a force of 500 SICBMs to be placed in Minuteman silos (in millions of FY99 dollars) were:

Development:	4925
Production:	15476
Construction:	100

TOTAL: $20.5 billion[12]

The last example of a deployed ICBM, the Peacekeeper, cost about $187M per missile, including all R&D, testing, and other costs, but the high cost per missile is misleading because of the small number of operational missiles (50) deployed.[13] The equivalent figure for Minuteman III, of which 500 were fielded, is $35M per missile.[14] Again, this amortizes all the non-recurring costs such as R&D and testing over the number of missiles fielded.

Preliminary cost estimates were developed in the BMR study. These are necessarily inexact, given the long lead times involved, and will go through many stages of refinement before an acquisition budget is eventually developed.

The BMR study will be followed by a formal Analysis of Alternatives (AoA). The AoA will take the options identified in the BMR study and analyze them using Cost as an Independent Variable (CAIV) and other tools to identify the optimum solution based on military utility as

well as affordability. The DoD-favored concept of CAIV requires examining the performance characteristics of a new system and looking at tradeoffs against lower cost.

In addition to cost and military utility, the development of the threat and the requirements of future arms control agreements (START III/IV) will be important factors in selecting a MM IV option. A final factor will be what happens to the Minuteman force over the next 20 years. For example, the need date may be impacted by on going aging and surveillance programs or depletion of assets through operational testing.

Options for Basing

Should the MM IV operate out of the existing Minuteman silos?

The BMR study made a presumption in favor of this option, given the long Air Force expertise in operating silo-based systems and the fact that missile silos already exist and do not need to be built. Fixed silos have always been subject to vulnerability concerns, although this is less of a problem in the post-Cold War era, where a mass counterforce attack is considered highly unlikely.

The U.S. has repeatedly examined rail-based and road-mobile ICBMs, both of which are used by Russia. However, costs and legal obstacles have shelved these plans, the most recent of which was for the SICBM (originally conceived as a mobile system).

Silo basing has strategic advantages. An attack on a silo-based ICBM force requires an enemy to use one or two warheads against each silo to have a reasonable chance of destroying the force.[15] That means 500 ICBMs would require an enemy to direct up to 1,000 warheads against them. This rules out the chance of a successful attack by any nation not possessing a very large force, since other targets must be attacked as well. This highlights the stabilizing value of ICBMs, as was noted by the DSB.

The strategic situation is continually evolving, and it's difficult to predict the threat beyond 20 years. The goal is to pursue concepts which preserve flexibility and potential for growth while preserving the inherent stabilizing value of the current MM III system.

Conclusion

All the options for the MM IV appear to be feasible. The analysis, research, and development should be initiated in the near term. The U.S. will continue to need an ICBM capability twenty years from now, and the pace and structure of the acquisition system dictates that the nation start thinking now about the capabilities the MM IV will need and the best way to supply those capabilities. The BMR study identifies a number of missions that could be met with a ballistic missile and documents initial operational requirements to meet those needs. The study identifies booster and front end options to meet those requirements. The planned AoA will look at these options, along with any others that may arise after the BMR study is completed in September 2000.

DISCLAIMER: While this paper is based on an AFSPC study, it is not to be taken as an official statement of policy. This paper does not represent the views, policies, or plans of Analytic Services Inc. (ANSER), Alliant Techsystems, TRW, the U.S. Air Force, the Department of Defense, or any branch of the United States Government.

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Major Jeffrey Schaff is the HQ AFSPC Directorate of Requirement's Command Lead for the Ballistic Missile Requirements study. He holds a B.S. in Industrial Engineering and an MBA. He has experience in ICBM missile operations and acquisition management. He has served in several Air Force Material Command System Program Offices.

Matt Bille is a Senior Research Analyst for ANSER. He holds a B.S. and a Master's degree in Public Administration and a Master's in Space Systems Management. Matt has worked on ICBM life extension programs for Air Force Space Command and published 15 articles and professional papers on space technology. He is a member of the AIAA's Space Operations and Support Technical Committee and the National Association of Science Writers.

Lamberth Blalock directs the Colorado office of Alliant Aerospace Company. He holds a B.S. and an M.S. in Business Administration. He spent 26 years in the Air Force in missile-related operations, staff, and command assignments, including tours in the Pentagon. He was the Deputy Director of Requirements for Force Applications in Air Force Space Command.

Stan Bailey holds a Bachelor's in Business and an MBA. As an Air Force officer, he directed the ICBM Requirements Office of Air Combat Command. He is currently the ICBM Program Manager for TRW's Space and Missile Systems Division in Colorado Springs.

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